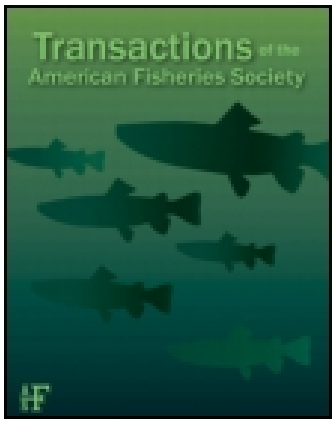

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External Attachment of Acoustic Tags to Deepwater Reef Fishes: an Alternate Approach When Internal Implantation Affects Experimental Design

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NOTE

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Abstract

Implanting internal acoustic tags is often a preferred method for tracking fish; however, this procedure can present issues with respect to surgical incision that affect experimental design. This is particularly the case when testing for the effects of barotrauma, where the incision for an internal tag would inadvertently "vent" the fish, precluding an "unvented" or control treatment. The rise of barotrauma experimentation has increased the need for methods facilitating this design. Here, we develop and test a novel technique to externally attach acoustic tags, without causing the release of gasses from the fish's body cavity. In addition, this method does not require anesthetics, thereby allowing researchers to eliminate artifacts associated with sedation when trying to more accurately replicate "real-world" fishery conditions. We used accelerometer/depth tags to provide information on how long an externally tagged fish would retain its tag in situ. Changes in acceleration or changes in depth were used as a proxy to determine whether the fish was alive or dead or had shed its tag. Results showed that 80% of the fish ($n = 20$) detected retained their tags for at least 48 h. Seventy-five percent of the fish tagged retained their tags for at least 23 d. After 23 d, tags were shed periodically until day 49. Thirty-three percent of fish tagged retained their tags until day 57, when the experiment was ended. The ability of these modified tags to stay attached for at least 23 d suggests that the technique would be successful for maintaining a balanced experimental design for measuring postrelease mortality or changes in behavior in deepwater fishes while eliminating artifacts typically associated with internal tag implantation.

As fisheries become intensely managed, there has been an increase in the number of regulations that restrict or eliminate harvest; however, fishermen routinely catch-and-release fish out of season or cull their catches (Brill et al. 2008; Cowan 2011). For deepwater fishes, the consequence of these management regulations is an increase in the number of fish released with barotrauma-related injuries (Burns et al. 2004; Brill et al. 2008; Hannah et al. 2008; Campbell et al. 2014). Studies testing the in situ effects of barotrauma and of methods (e.g., venting) that may mitigate pressure-related injuries have been limited by the complexities of working with deepwater fishes and by artifacts associated with experimental techniques describing the fate of the released fish (Wilde 2009). Acoustic telemetry offers a viable means to test these mortality reduction techniques under natural conditions (Whitney et al. 2007, 2013).

Barotrauma can cause a multitude of problems as gasses expand within a fish's body during the rapid ascent from depth to the surface. The result is that internal organs can be

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compressed as the swim bladder expands and ruptures, the eyes may be damaged due to exophthalmia, stomach eversion can occur, and emboli can form within various tissue structures, resulting in tissue damage (Burns et al. 2002; Rummer and Bennett 2005; Rummer 2007; and references within Wilde 2009). The immediate consequences are highly variable, even within a species of fish. Fish captured from identical depths can have differing degrees of barotrauma, ranging from no obvious effects to death. The indirect effects of barotrauma are not as easily identified and have been studied even less. Barotrauma may indirectly result in increased predation rates upon release, delayed mortality, or decreased growth rates. Mitigating the effects of barotrauma and quantifying delayed mortality have been identified as being critical toward proper fisheries management (Rummer 2007; Diamond and Campbell 2009; Drumhiller et al. 2014).

One of the greatest impediments toward quantifying the effects of barotrauma is the inability to monitor and track a fish's fate postrelease while maintaining a well-balanced scientific design without introducing substantial experimental artifacts such as studies where movement are restricted (e.g., caging) or handling times are long (e.g., internal tagging). Using a traditional passive tagging approach can better replicate actual fishery conditions, but this requires extensive numbers of tagged fish and can result in the unintentional venting of barotrauma-related gasses (Campbell 2008; Campbell et al. 2010), depending on tag type or tagging location. For example, because of the higher retention rates, placing an anchor tag in the abdominal cavity is the preferred method for tagging species such as Red Snapper *Lutjanus campechanus*, but this results in venting of the cavity (Szedlmayer and Shipp 1994; Patterson and Cowan 2003). However, the principal issue with these studies is documenting the fate of unrecovered fish. Fish can also be captured and caged at an a priori depth to maintain a nonvented treatment (Gitschlag and Renaud 1994), but this technique results in a situation where a fish is forced to remain at a depth preferred by the researcher and not at a depth where it may naturally relieve pressure-related barotrauma symptoms (Campbell et al. 2010). Additionally, current protocols for acoustic telemetry recommend fish be anesthetized and held for extended periods of time to ensure recovery from a surgical internally implanted tag. Such methods introduce artifacts associated with handling and the effects of anesthesia on behavior. Additionally, by not immediately releasing the fish back into its environment, researchers lose the ability to replicate realistic fishing conditions. Finally, and most importantly, when an acoustic tag is placed into the abdomen, the gasses are unintentionally vented, eliminating control treatments. As such, testing methods necessary to mitigate the effects of barotrauma requires the development of a technique that minimizes the potentially confounding artifacts associated with restricting postrelease fish movements, unintentional venting during tagging, and reducing handling times.

The objectives of this study were to develop and test a technique for rapid, external attachment of acoustic tags to enable the maintenance of nonvented controls in barotrauma experiments on deepwater fishes using Red Snapper as a model deepwater species. In the Gulf of Mexico (Gulf), Red Snapper are one of the most important commercial and recreational fish in the Gulf (Gallaway et al. 2009) and are currently experiencing a greatly reduced harvest. The result is a limited harvest season (~9 d in 2014), causing the fishery to be a catch-and-release fishery that experiences a heavy discard rate. Red Snapper have also been on the forefront of fisheries research in the Gulf (see Gallaway et al. 2009; Cowan 2011); however, work pertaining to barotrauma in Red Snapper has been limited (e.g., Rummer 2007). Red Snapper routinely experience significant barotrauma when captured (Burns et al. 2002, 2004; Diamond and Campbell 2009; Drumhiller et al. 2014), but little is known about the delayed mortality or the ecological impacts of barotrauma once a fish is released (Drumhiller et al. 2014). The techniques suggested here will build upon these initial studies and lead to improved accuracy of the estimates so obtained (e.g., Gitschlag and Renaud 1994; Gitschlag et al. 2000; Patterson et al. 2002; Diamond and Campbell 2009).

METHODS

Tag design and pilot testing.—Fish were tagged using an accelerometer equipped VEMCO V9 AP tag. The V9AP has a length of 46 mm, a diameter of 10 mm, and a weight of 3.5 g with a lifespan of 50–60 d. In addition to measuring and transmitting fish movement through the water column via the accelerometer, the tag also measures pressure (i.e., depth) and transmits a ping to report the presence or absence of the tag within the listening radius of the hydrophone. Acceleration was calculated as a value resulting from the contribution of acceleration from each of the *x, y*, and *z* axes according to the following formula (D. Webber, VEMCO, personal communication):

$$|g| = [(xg)^2 + (yg)^2 + (zg)^2]^{-2}.$$

Acceleration (g) was measured in ms^{-2}, and values in g from each axis were integrated into a single absolute value (Whitney et al. 2007). When attached using a technique that does not allow secondary movements of the tag (e.g., Whitney et al. 2007, 2013), this tag produces a value only while the fish is moving. As such, a positive acceleration value combined with a changing depth value can be used as a proxy for a fish that is alive and moving (Whitney et al. 2007; Broell et al. 2013). Negative acceleration, or a value near zero, combined with a stationary depth indicates the tag is no longer moving, possibly due to death or tag shedding. One requirement of the accelerometer is that its long axis must remain perpendicular to the force of gravity (Webber, personal communication). Our attachment technique ensures this position is maintained, similarly to surgical implantation in the abdominal cavity.

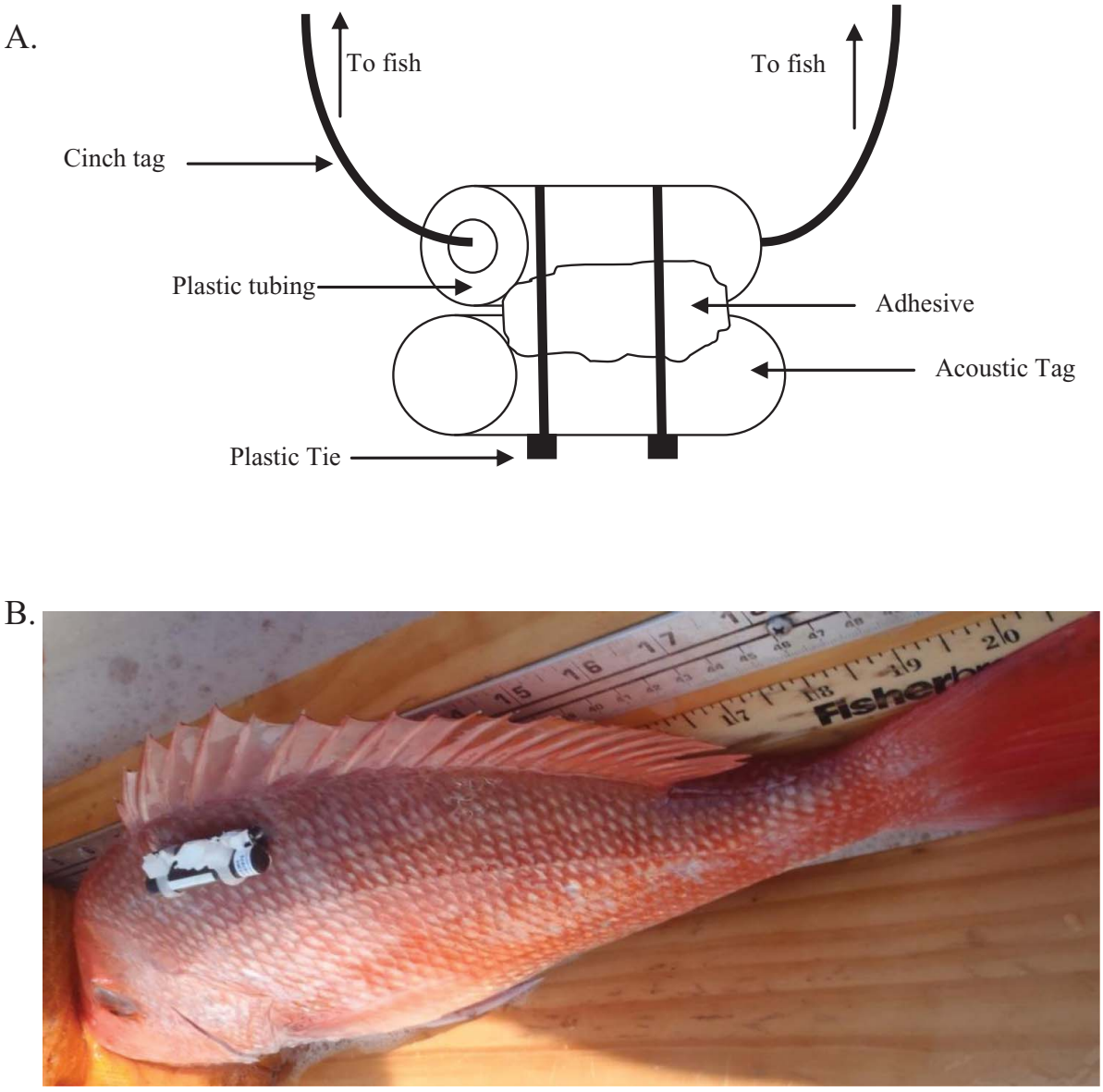

FIGURE 1. **(A)** Diagram of modified VEMCO V9-AP tag used in this study. Tags were attached to the fish by passing a 13-gauge syringe needle between the 2nd and 3rd pterygiophores of the first dorsal fin approximately 1.5 cm below the dorsal edge of the fish creating a channel for insertion of a loop tag through the fish. This process was repeated between the 4th and 5th pterygiophores to pass the loop tag back to the original side of the fish where the acoustic tag could be threaded onto the loop before it was secured to itself and pulled snug. **(B)** Photo of a tag after attachment to the fish. [Figure available online in color.]

The external tagging technique was developed under the advice and guidance of Douglas Posey (Southside Animal Clinic, Corpus Christi, Texas) as part of the Texas A&M University of Corpus Christi's Institutional Animal Care and Use Committee (IACUC Permit 02-11). Under this guidance, a technique was developed that minimized stress to a level similar to that of other commonly used tagging procedures in which a fish feels only momentary pain, similar to the insertion of two standard dart tags. The result was a technique that decreased handling time from that needed in internal tagging procedures and no longer required the need to make the body cavity incision required for an anchor tag. This technique has the potential to minimize handling stress, pain, and potentially improve survival.

To enable external attachment, we modified the tags by first using a waterproof adhesive (3M Marine adhesive/Sealant 5200) and cable ties to attach a piece of steel-reinforced rubber tubing (inside diameter, 6.35 mm) in a parallel direction to the tag (Figure 1). The adhesive was allowed to cure for 7 d, according to the manufacturer's directions. The tube was cut to approximately 40 mm long so it would not interfere with the pressure sensor located at the end of the tag. Because of the frequency of the tags and because only a small acoustic void area would be created where the tubing contacted the tag,

this technique did not substantially attenuate the acoustic signal being produced by the tags.

Pilot laboratory trial.—The modified acoustic tags were attached to fish by passing a 13-gauge syringe needle between the 2nd and 3rd pterygiophores of the first dorsal fin approximately 1.5 cm below the dorsal-edge of the fish, creating a channel for insertion of a Floy-Tag FT-4 Cinch-up loop tag through the fish. This process was repeated between the 4th and 5th pterygiophores to pass the loop tag back to the original side of the fish where the acoustic tag could be threaded onto the loop before it was secured to itself and pulled snug. For the preliminary tagging trails, three fish were tagged by placing fish dorsal side up in a V-shaped measuring cradle inside a 66-L rectangular container where movement could be restricted and the head and gills could be kept submerged for the duration (Figure 1). This exposed the dorsal surface of the fish, where the tag could be attached. Care was taken to not impede fish movement while maintaining the acoustic tag perpendicular to the force of gravity. External attachment of tags using a similar technique has been used successfully on several other species (Bridger and Booth 2003; ICCAT 2014).

Because previous caging experiments showed that most barotrauma fatalities occurred during the first 4 d after release (Gitschlag and Renaud 1994; Burns et al. 2004), we conducted a 4-d pilot study using activated tags on fish held in a 1-m-deep 4-m-diameter recirculating system. This trial was to assess tagging-related mortality and to ensure that acceleration values could still be collected using the modified tags. This trial was conducted on three Red Snapper that were captured locally 14 d earlier from a depth of about 20 m. At the start of the trial, the fish were showing no sign of barotrauma or abnormal behavior and were actively feeding. According to Burns et al. (2002), 14 d was sufficient to allow for recovery from any barotrauma injuries present. Because Red Snapper are structure-oriented fish and often found in confined spaces, additional vertical polyvinyl chloride piping was added to the tank to provide ample surfaces for a fish to manually remove the tag at its discretion. A hydrophone was also added to the system to receive the signal from the tags. Fish were maintained for 4 d, and food was provided to them daily to satiation. At the end of the trial, the fish were recaptured and the tags removed.

Field experiment.—Approximately 30 Red Snapper were collected and 22 were tagged during the winter of 2009, using hook-and-line in a manner identical to the techniques used by recreational fishermen. For a control treatment for barotrauma injuries, we tagged and released an additional four fish that had been captured approximately 14 d prior to the experiment from a location 20 m in depth and allowed to recover from any barotrauma or capture related injuries (Burns et al. 2002). Since most barotrauma injuries are not externally visible (Burns et al. 2002; Rummer 2007), this technique was the most effective approach we could develop for a control treatment, where the fish were in a "natural" state physically. Additionally, it would have been difficult, if not impossible, to capture red snapper at a depth on-site where barotrauma injuries would be guaranteed to not occur, potentially introducing additional artifacts into the experimental design.

This experiment was conducted with permission at a petroleum production platform (MU 762A) owned by Apache Corporation and located 42 km (27.4147N, 96.3449W) southeast of Port Aransas, Texas, in 50 m of water. Fish size was 504 ± 4.0 mm TL (mean ± SE), had an average fight time of 47 ± 0.8 s, and an average time on deck of 139 ± 1.5 s. Upon capture, the fish were placed into a V-shaped trough within a rectangular tank with their heads submerged and dorsal area exposed and examined for of barotrauma injuries. Fish with catastrophic barotrauma injuries (e.g., moribund, bleeding from gills, inability to move) were not tagged as it was expected that they would not survive. Tags were attached as quickly as possible, typically in less than 90 s, and fish were randomly assigned to an experimental treatment group. These groups were surface-released fish or hook-released fish. The hook-released fish ($n = 10$) were released at the seafloor, attached to a weighted hook that forced them back near capture depth (Shelton Fish Descender). A descender hook was used because it is a commonly accepted technique used by fishermen to return a fish to depth. Briefly, a descender hook is placed through the soft tissue in the mouth and then the fishermen releases the weight to pull the fish back to depth where it is released. The surface-released fish (treatment, $n = 10$; controls, $n = 4$) were released at the surface and allowed to freely swim back to depth at will through a 1.5 m^2 floating cage with no bottom. This cage allowed for the recovery of any fish that could not resubmerge so the tag could be redeployed. None of the fish used in this experiment trial were vented to release gasses from the abdomen.

Data from the acoustic tags were collected by 2 VEMCO VR2W receivers mounted by scuba in the middle of the platform structure at 11.9 and 27.5 m below the surface. Two receivers were used to minimize the impact of thermoclines inhibiting sounds from passing through the water column (Nieland et al. 2007). Because the tags were set to transmit randomly at some point between 17 and 90 s, it was possible to detect at approximately what point in time the tag ceased moving within the array or left the array (Figure 2). Acceleration or changes in depth were indicative of a fish that was alive, but the lack of movement could be attributed to either tag shedding or fish death. Discerning between the two is somewhat subjective without tag recovery. Because data transmitted from the tags were given a unique identifier, data from both receivers were combined and duplicates were discarded. Additionally, a tag transmission was recorded only if the entire data stream was received by the receiver, as such; tag collisions reduced the total number of recorded pings, but this ensured that all the data transmitted by a tag were collected. Using a portable hydrophone, we determined the detection range of the receivers was between 400 and 600 m during a preliminary range testing period.

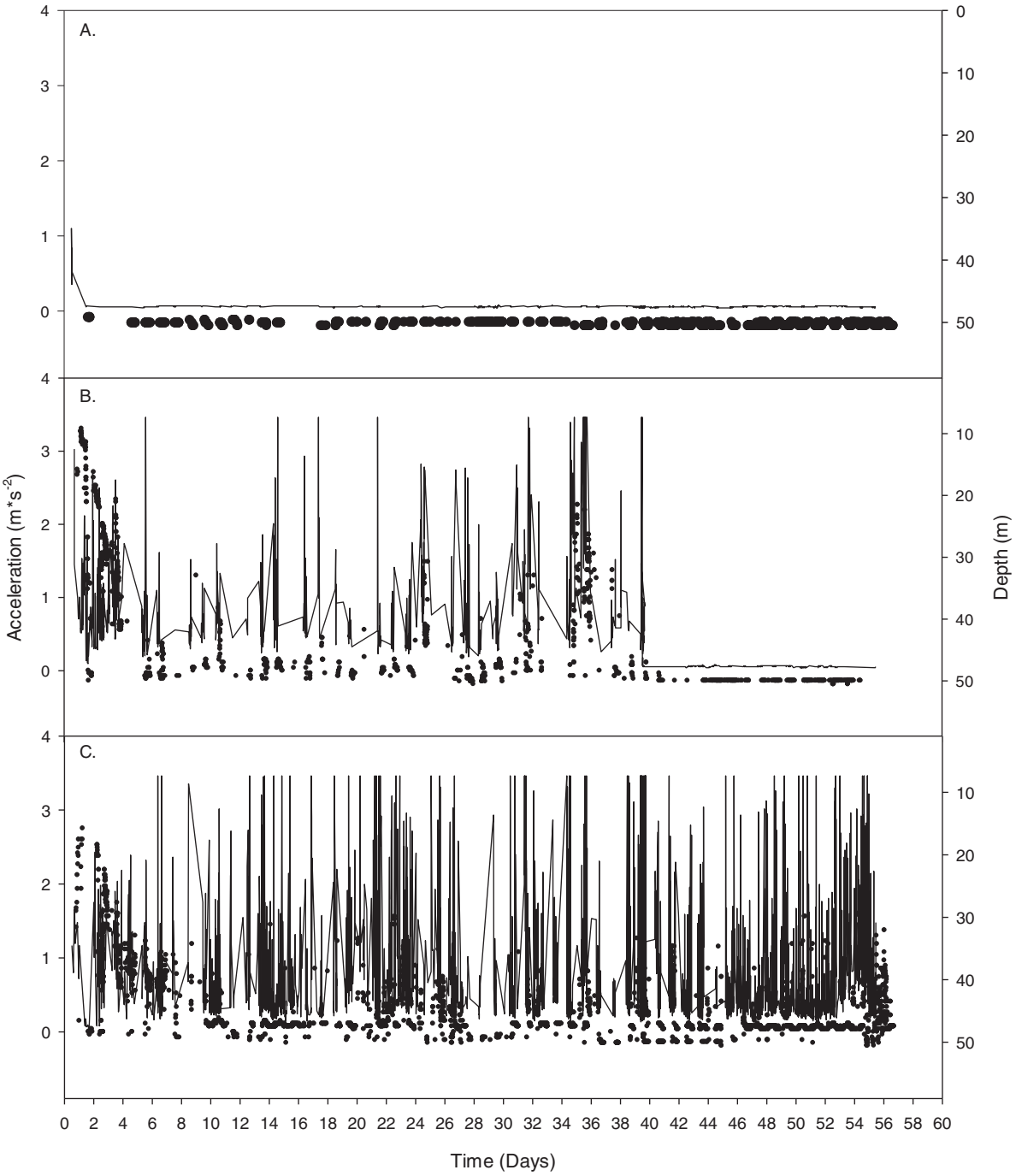

FIGURE 2. Examples of the three different types of plots to evaluate tag shedding. Lines represent acceleration (left axis) and dots represent depth (right axis). **(A)** Results for fish that died within the first 96 h of experiment; **(B)** results typical of fish that shed tags between day 4 and 57; **(C)** results typical for fish where tags remained in place for the duration of the experiment. Straight lines between acceleration points represent periods of time when no values were recorded.

To discern whether fish had died or shed the tag, we combined information suggesting that barotrauma-related delayed mortality is most likely to occur during the first 4 d after capture (Gitschlag and Renaud 1994; Burns et al. 2004) with the results from our pilot study. At the end of 4 d, 100% of the fish survived and were feeding aggressively with no tag shedding. Thus, we considered any lack of changes in depth or acceleration during the first 4 d to be the result of mortality rather than tag loss. After 4 d, the lack of movement by a tag was interpreted as tag shedding or fish death not associated with barotrauma rather than a fishing-related mortality event.

To determine whether differences in shedding rates were present among the groups, we used a Kaplan–Meier Log Rank Survival Analysis (SigmaPlot v.12.3), excluding any tags that stopped moving during the first 4 d (Kaplan and Meier 1958; Efron 1988). If no differences were present in the Log Rank Analysis, all three groups were combined and a Kaplan–Meier Single Group Survival Analysis was used to model the data set. Because several individuals were still alive at the end of the experiment, the data set was right-censored at 57 d because that was when the receivers were retrieved and was beyond the predicted life of the acoustic tag.

RESULTS

Overall, results showed that this external attachment method was successful at enabling a more complete analysis of the effects of barotrauma as it relates to the effects of fishing. Twenty-two Red Snapper were successfully captured, tagged, and released; however, two fish were unable to resubmerge because of gasses trapped within the abdomen and died at the surface. These fish were retrieved and their tags placed on newly captured fish for a total of 20 fish that were released alive. Four control fish were tagged and released, and all were able to submerge immediately. All fish used for the experiment were hooked in the side or top of the mouth using circle hooks, and each showed some degree of pressure-related symptoms, including distended stomachs, firm abdomen, protruding anus, or subcutaneous gas expulsion.

Of the 20 fish in the treatments, receivers detected 16 (80%) fish for at least the initial 48 h of the experiment. All fish initially detected retained tags for at least 20 d. Fifteen tags showed acceleration (movement) until day 23, when Red Snapper began to shed tags. Tag shedding continued and was observed at days 27, 31, 36, 37, 40, 44, and 49. After the second day, acceleration values for two fish changed from actively moving to zero acceleration values. Additionally, the pressure values corresponded to a depth of approximately 50 m, coincidentally the depth of the seafloor, suggesting that the fish had died. Although no movement was occurring, these tags continued to be detected by the array for the experiment duration. All shed tags remained within the array and were continuously detected for the duration of the experiment as indicated by zero acceleration values at approximately 50 m in depth (Figure 2). A total of five tags remained on the tagged Red Snapper for the duration of the experiment (57 d) and continuously transmitted acceleration and depth values (Figure 3). For the control fish, three of the four were detected by the receivers beyond the initial 48 h. One control fish was never detected, suggesting that it quickly swam away from the array detection zone or perhaps was captured by a predator that left the area before a transmission could be detected by the receiver. All tags had been testing and functioning prior to attachment and deployment. By the fifth day, one surface and one bottom-released fish had left the array, although the

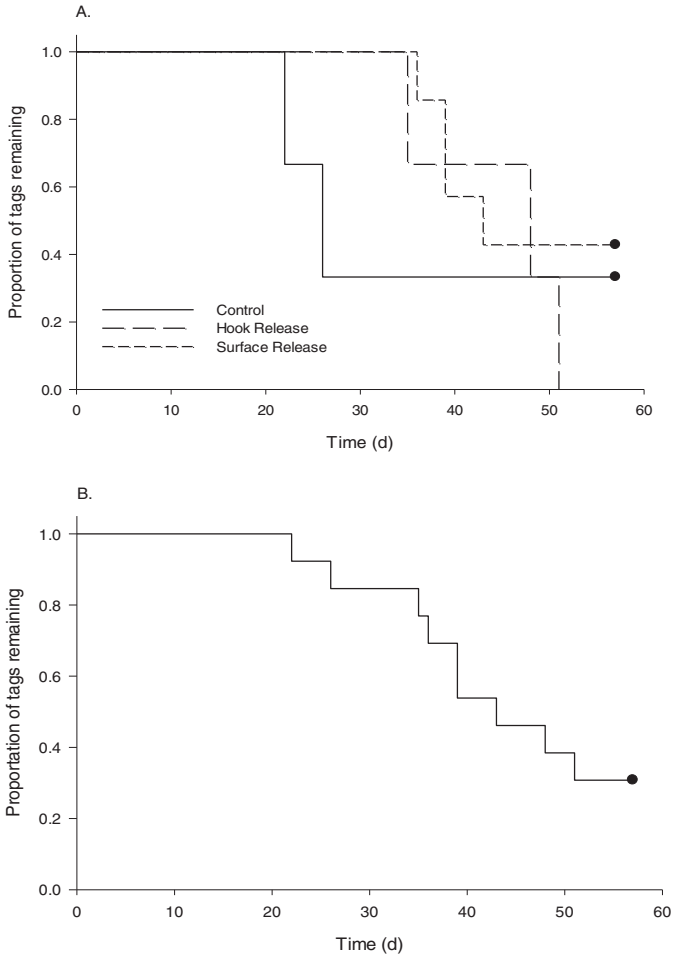

FIGURE 3. Kaplan–Meier survival curve for all tags that communicated continuously throughout the experiment. **(A)** Analyses for each treatment; **(B)** analyses for all treatments combined. Circles signify the end of the experiment.

surface-released fish later returned and was detected with an acceleration of approximately 2 m s^{-2} on day 40, suggesting that it remained alive but initially had left the area.

Forty-three percent of the tags remained in place for the duration of the experiment and were able to relay presence, depth, and acceleration information across than entire time period. The mean (±SE) amount of time the tags remained in place was 43 ± 3.4 d. The median amount of time tags remained in place was 43 ± 5.4 d with 75% of the tags remaining after 36 ± 8.3 d. The control group was the first group to shed tags with 33% (one of three) remaining after 26 d, but that one remaining tag stayed attached for the duration of the 57-d experiment. The bottom- and surface-released fish did not have any tag shedding until day 35; however, after that, the bottom-released fish shed all tags by day 52. Surface-released fish shed tags between day 37 and 43.

For tags that communicated continuously with the receivers throughout the 57-d experiment, log-rank test of the survival curves survival estimates did not result in any significant

differences among the three groups (log-rank statistic = 1.064, df = 2, $P = 0.587$; Figure 3). Accordingly, a single Kaplan–Meier survivor curve was calculated using all data combined. Mean (±SE) survival time was 43.6 ± 3.4 d, the 95% confidence interval being between 36.9 and 50.3 d (Figure 3). Five fish survived beyond the end of the experiment.

DISCUSSION

As new and often expensive technologies are developed in the field of fisheries-related acoustic telemetry, understanding tagging-related artifacts and the development of species-specific tagging techniques is essential to advancing our state of knowledge concerning fisheries ecology and management. Improving tagging techniques will reduce mortality and minimize the introduction of surgery-related bias and experimental artifacts (Cooke and Wagner 2004; Harms 2005), especially for tags that have the ability to transmit movement and behavioral information. Together, these results demonstrate that this technique can provide key information about fish behavior in situ during a postbarotrauma period of recovery while enabling experimental designs that can maintain experimental treatments in which having an nonvented treatment group is desired and acoustic tagging is the preferred technique.

This external tagging technique allows researchers performing short-term experiments to externally tag fish without having to perform invasive surgery, which often prevents certain treatments in a study design, especially experiments that do not require venting for barotrauma studies. Using this technology, many different techniques used to release deepwater fish can be tested more completely before being implemented into management decisions. Detection of tagged fish in our study (83% of fish released showed animal movement for at least 48 h) was similar to that of previous studies where fish were tagged internally and held for a period of postsurgery observation (Schroepfer and Szedlmayer 2006; McDonough and Cowan 2007; Westmeyer et al. 2007; Topping 2009). This suggests that our technique is a viable option for short-term experiments (20–30 d) using tags that can provide increasing amounts of information. Moreover, this is the first attempt to determine whether acoustic tags configured to report acceleration could be used in Red Snapper research as a tool to measure the effects of barotrauma by providing movement and acceleration information, not just presence and absence.

The fish that did not die due to their initial treatment retained their tags for at least the initial 23 d of the experiment. During this substantial length of time, no fish were lost, and a substantial amount of data was collected with respect to fish presence, depth preferences, and acceleration. This period of time should be more than adequate to experimentally test whether barotrauma had any influence on behavior patterns of released fish. However, if longer tag retention is required, such as in longer-term migration studies, investigators should choose the tagging that best suits the goal of the research. In the laboratory, 4 d was adequate for fish to return to feeding after a barotrauma injury (Burns et al. 2004; Drumhiller et al. 2014); often, less time was required, and most began feeding the same day they were tagged. In the field, tag retention of at least 21 d is adequate time to allow for reestablishment of normal behavior patterns and for experiment- or capture-related mortality to be determined (Gitschlag and Renaud 1994; Burns et al. 2004). To reduce tag shedding and extend the useful life of the tags beyond a 21-d period, replacing the cinch tag with a more durable material (e.g., stainless steel or aluminum wire) may help expand the observation window to a length more appropriate for discriminating different behavior patterns among treatments. We recommend that future studies assess different types of material to improve retention times.

One aspect of this study that differed from the majority of previous acoustic tagging experiments is that it was conducted in a manner to minimize stress during tag attachment by not using anesthesia during the tagging process and rapid attachment of the tag (Szedlmayer 1997; Szedlmayer and Schroepfer 2005; Peabody and Wilson 2006; McDonough and Cowan 2007; Westmeyer et al. 2007; Topping 2009). The ability to rapidly attach acoustic tags externally to Red Snapper provides researchers increased flexibility to design experiments that better replicate complex and relevant fisheries issues in the field that could be confounded by the use of anesthesia influencing postrelease behavior, internal tagging, attempts to replicate fishery conditions, or when federal regulations prevent the use of anesthetics when releasing fish that have the potential for human consumption. In our experiment, mortality associated with external tagging remained similar to previous experiments, suggesting that conducting an experiment without anesthesia combined with rapid tag attachment is a plausible technique for acoustically tagging fishes to maintain treatment levels. For example, for Peabody and Wilson (2006), anesthesia resulted in 3% of the fish not recovering from the surgery process while Topping (2009) had 20% of the fish released die within 6 d of surgery.

Certainly, this type of experiment without anesthesia must be approved and performed under guidance of Institutional Animal Control and Use Committees and may not be acceptable in some cases. This study was approved by and overseen by a consulting veterinarian and other animal use experts to minimize pain and distress. It is possible that by not using anesthesia we may introduce some level of immediate discomfort to the fish; however, the tagging process was very rapid (~90 s). Red Snapper are routinely tagged using a needle or a small incision to insert passive tags without sedation by other researchers (Szedlmayer and Shipp 1994; Burns et al. 2002; Patterson and Cowan 2003; Diamond et al. 2007); as such, our veterinarians and our tagging team are confident the discomfort inflicted by our process is momentary and similar to that of external "dart-type" tagging for tag-and-release studies routinely conducted without anesthesia. In fact, these experts conclude that, given the rapid procedures described here, this

process likely causes less discomfort and distress than do traditional surgical implants and often complicating anesthesia effects (D. Posey, personal communication). Overall, we suggest the amount of discomfort is, at a minimum, equivalent to handling and sedating a fish. The rapid release of the fish back into a habitat, where it can self-regulate the correct depth to facilitate healing, offsets the additional stress associated with sedation, surgery, and recovery periods, especially for fish experiencing extensive barotraumatic injuries. Finally, these notions are supported by our in-laboratory preliminary trials, where all fish quickly returned to normal behavior patterns in less than 4 h and started feeding aggressively within a few days.

As in almost any field experiment, these techniques do introduce artifacts into the analysis. The most obvious issues are (1) the drag in mobility associated with an external tag and (2) distinguishing between a death and a tag-shedding event. The artifacts of an external tag were expected to be minimal given the small size of the tag, the robust nature of Red Snapper, and the extensive historical use of external tags throughout fisheries sciences. Of more concern is the possibility that some of the fish were mistakenly categorized according to our schema. It is possible that some of the fish considered to have died actually just shed a tag and that some of those that shed their tags after 4 d were actually deaths. Ideally, recovery of a tag close to the time the data indicate it has stopped moving would confirm or refute our assumptions on how accurate is the 4-d period for assessing that postrelease mortality is most probable. However, many previous experiments show that within 4 d (and often much less) of tag implantation, fishes, including Red Snapper, have either died or are actively feeding and resuming normal behaviors (Gitschlag and Renaud 1994; Thoreau and Baras 1997; Fabrizio and Pessutti 2007; Campbell 2008; Drumhiller 2012). Regardless if the categorization of tags that stop moving proves to be completely accurate, this technique provides valuable insight into patterns of behavior and use of the water column for the fish that do retain their tags. To gain a more complete picture of tag shedding, we suggest that expanded treatments and use of a longer time period should be performed beyond this initial experiment.

In summary, given the rapid expansion of acoustic tagging, the ability to continually develop new experimental techniques for researchers to take advantage of emerging technology is critical to answer pressing questions from fisheries management. This study shows that fish can be tagged without anesthesia, and that tags designed for internal implantation can be adapted for external use. Specifically, this technique will expand researchers' abilities to better incorporate the effects of barotrauma into experimental design, at least in the short term, to more accurately replicate fishery conditions, and to expand our understanding of habitat use and fish movement in deepwater catch-and-release fisheries.

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